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APPLIED PHYSICS LETTERS, vol. 47, no. 10, 15th November 1985, pages 1095-1097, American Institute of Physics, Woodbury, New York, US; R.W. BOSWELL et al.: "Pulsed high rate plasma etching with variable Si/SiO2 selectivity variable Si etch profiles",

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Description

The present invention is concerned with a method for etching and is particularly concerned with a plasma etching method.

In particular, the present invention is concerned with a plasma etching process that exhibits an enhanced or increased etching rate. The plasma etching process of the present invention is especially useful in fabrication processes in the electronics industry such as involved in packaging of integrated circuit chips.

In the fabrication of integrated circuits, a number of the steps involved, for instance, in preparing integrated circuit chips and the packaging for the chips (articles to which the chips are attached and protected), are etching processes. Accordingly, over the years, a number of vastly different types of etching processes to remove material, sometimes in selective areas, have been developed and are utilized to varying degrees. One such etching process is referred to as "plasma etching". This type of etching procedure generally involves filling a container such as a bell jar with a gas whose dissociative fragments are chemically reactive. An example of such a gas is CF_4. The surface that is to be etched is introduced into the container, along with the reactive gas. In the event the surface to be etched is to be etched only in certain predetermined areas, such surface would previously be covered by a mask to prevent etching in the areas not to be etched. The feed gas is usually disassociated, forming positive and negative ions, electrons, and reactive neutrals by coupling radio frequency power to the plasma by a capacitative or inductive coupling. It is believed that the reactive fragments then chemically interreact with the surface to be etched. In such a process, the substrates may be positioned either on a ground plane on the rF driven electrode (cathode) or on an electrically insulated carrier.

Plasma etching has been used to a significant extend, depending upon the particular reactive gas employed for etching both organic and inorganic materials. Such materials include polyimides, polyepoxides, photoresists, and silicon.

A pulsed high rate plasma etching method is disclosed in Appl. Phys. Lett. 47 (10), 15 November 1985, page 1095-1097, Boswell et al., "Pulsed high rate plasma etching with variable Si/SiO_2 selectivity and variable Si etch profiles". By periodic power interruption between 0 and 500 Watt, very high etch rates of Si in SF_6 have been obtained.

GB-A-2,105,729 discloses a process for the surface processing of substrate material, such as heat-sensitive plastics. By applying a high frequency pulsed electrical field to a non-specified gas, a plasma for surface processing is produced.

EP-A-0,203,560 discloses a process for etching trenches in silicon using CF_3Br gas in an annular flow plasma reactor. A glow discharge is caused by applying pulsed RF power to said reactor.

For instance, polyimides are used to a large extent as insulation between two layers of metallization in multilevel metallization articles such as metallized ceramics. In such articles, two layers of metal, such as aluminum, an aluminum alloy, or copper are separated by a layer of insulating dielectric material such as a polyimide that contains vias in a predetermined pattern. The vias in the polyimide dielectric layers are formed by plasma etching. The gas employed, whose dissociative fragments are chemically reactive for etching polyimides include CF_4 and oxygen, and mixtures thereof.

The present invention is concerned with a method of etching an article by plasma etching whereby the etching rate is significantly increased. In particular, the method of the present invention includes positioning the article to be etched on a cathode and enclosing the cathode and the article to be etched in a chamber. An etchant gas is introduced into the chamber and power applied to the cathode is cycled between a lower wattage value and a higher wattage value to thereby enhance the etching rate. It has been found in accordance with the present invention that the etching rate achieved by employing an oscillating mode for the power is significantly higher than the rate obtained at any power at or between the limits of the power oscillations employed.

Figure 1 is a schematic diagram of apparatus that can be used to carry out the process of the present invention.

Figure 1 depicts diagramatically an apparatus suitable for carrying out the process of the present invention. In Figure 1 there is illustrated a vacuum envelope 1 that includes a base plate (2) and bell jar (3), such as a glass or metal bell jar that is hermetically sealed to the base plate (2). The volume of (1) vacuum envelope employed in the present invention typically is about 50 liters. Within the vacuum envelope (1) is a cathode (4).

The cathode is an electrode that is preferably driven by a radio frequency power source (not shown). However, the cathode can employ power sources at other frequencies.

The cathode (4) is usually copper and, if desired, can be provided with a conduit for providing coolant to maintain the temperature of the cathode sufficiently low so as not to endanger degradation of the article being etched. Other metals for the cathode include aluminum and stainless steel.

The article to be etched is placed atop the cathode. The vacuum envelope includes an exhaust means (6) for evacuating the space enclosed in the vacuum envelope and is connected to a pumping means (not shown). The envelope can thereby be evacuated prior to subjecting the articles to the process of the present invention. The envelope also includes a conduit (7) for introducing the feed gas into the vacuum envelope.

In addition, it may be desirable to include an ion shield such as quartz shield (10) in order to separate the article being etched from bombardment by energetic ions from the plasma while allowing attack of the article (5) to be etched by reactive neutrals.

Also provided in order to monitor the etch rate is a laser interferometer system, such as one having a laser (8) operating at a wavelength of about 632.8 nm, and a photodiode detector (9). The combination of laser (8) and photodiode (9) is referred to as a Laser Interferometer.

The articles to be etched in accordance with the present invention include a substrate and the surface thereon that is to be etched. Such substrates can include inorganic materials such as silicon and silicon oxide and organic materials including thermoplastic and thermosetting polymers.

Examples of some organic materials are polyimides, polyamides, epoxy resins, phenolic-aldehyde polymers, polyolefins such as polypropylene and polyethylene, and the various known photoresist materials.

A typical photoresist material is one based on phenol formaldehyde novolak polymers. Particular examples being Shipley 1350™ which is an m-cresol formaldehyde novolak polymer composition. Such is a positive resist and includes therein a diazoketone such as 2-diazo-1-naphthol-5-sulphonic acid ester.

A discussion of photoresist materials can be found, for instance, in Journal of the Electrochemical Society, Volume 125, No. 3, March 1980, pp. 45C-56C, Deckert et al., "Microlithography - Key to Solid-State Fabrication", disclosure of which is incorporated herein by reference. Of course, the reactive gas to employ in any particular process will depend upon the particular material being etched.

The preferred materials to be etched in accordance with the present invention are the polyimides. When the process is used in preparing patterned articles, a mask, for instance, of a photoresist or electron beam resist material is applied on top of the surfaces to be etched.

The etchant gas employed will depend upon the particular material being etched and such are well-known in the art. For instance, when a polyimide is being etched, the etchant gas generally includes a gaseous fluorocarbon capable of supplying fluorine. Examples of such gases are CF_4, CHF_3, and C_2F_6. The fluorocarbons also supply CF_3^+ ions. Also for polyimides, oxygen is a well-known etchant gas. Mixtures of oxygen and a gaseous fluorocarbon can be employed if desired. The preferred etchant includes a mixture of about 1 to about 50 parts by volume of the fluorocarbon and about 99 to about 50 parts by volume of oxygen, and more preferably about 10 to about 40 parts by volume of the fluorocarbon and about 90 to about 60 parts by volume of the oxygen.

It is essential in accordance with the present invention that the power applied to the cathode be cycled or oscillated in order to achieve the enhanced etching rate obtained by the present invention. The frequency of the cycling or oscillation is related directly to the residence time of the reactive gas in the chamber. In other words, the faster the gas moves through the chamber, the quicker the frequency of the oscillation must be in order to go from one limit to the other limit of the power cycle while the gas is still in the reaction chamber in order to achieve the most beneficial effects of the present invention. For best results, the power is in a pulsed or cyclic mode during the predominant part of the etching and most preferably during substantially all of the etching procedure. In a typical arrangement wherein the chamber size is about 45 cm (1 1/2 feet) in diameter and about 25.4 cm (10 inches) in height, the power is cycled from about 50 watts to about 500 watts and back again. The gas flow rate is generally such that the gas flows through the chamber in about 1 to about 30 seconds. The gas flow rate is generally about 10 to about 200 standard cubic centimeters per minute, a typical value being about 100 standard cubic centimeters per minute. The pressure in the chamber is generally about 1.33 to 665 μbar (1 to 500 millitorr), typical value being about 133 μbar (100 millitorr).

The temperature of the cathode is generally maintained at about room temperature to about 100 °C during the etching process.

The following non-limiting Example is presented to further illustrate the present invention:

EXAMPLE

A silicon wafer having a diameter of about 8.5 cm (3 1/4 inches) is coated with a solution of polyamic acid by spin-coating. The film is dried and cured by subjecting the film to elevated temperatures. In particular, the temperature is raised from about room temperature to about 360 °C in about 1 hour, held there for about 0.5 hours, and then cooled down to about room temperature in about 1 hour. The thickness of the coating after curing is about 10 microns.

The coated substrate is then placed in a vacuum chamber of the type illustrated in Figure 1 and subjected to a radio frequency power oscillated between about 50 watts to 500 watts with a period of about 2 seconds during exposure to a mixture of CF_4 and oxygen in a ratio of about 1 to about 4. The gas flow rate employed is about 100 standard cubic centimeters per minute and the pressure in the vacuum chamber is about 133 µbar (100 millitorr). The chamber employed is about 45 cm (1 1/2 feet) in diameter.

The etch rate for the polyimide is about 140 nm per minute as compared to only 80 nm per minute when employing a radio frequency power of about 50 watts and about 90 nm per minute when employing a radio frequency power of about 500 watts.

Claims

1. Method for etching an article by plasma etching wherein said article includes a substrate and a surface of organic material thereon which comprises:
positioning the article to be etched on a cathode;
enclosing in a container the cathode and the article to be etched;
introducing an etchant gas into said container, wherein said etchant gas is a mixture of a fluorocarbon and oxygen; and
applying power to the cathode wherein the power is cycled between a lower wattage value and a higher wattage value to thereby enhance the etching rate of the organic material.

2. Method of claim 1 wherein said organic material is selected from the group consisting of polyimides, polyamides, epoxy resins, phenolic-aldehyde polymers and polyolefins.

3. Method of claim 2 wherein said surface comprises a polyimide.

4. Method of claim 1 wherein said gas includes a fluorocarbon selected from the group of CHF_3, CF_4, and C_2F_6.

5. Method of claim 4 wherein said gas includes CF_4.

6. Method of claims wherein said gas is a mixture of about 1 to about 50 parts by volume of CF_4 and about 99 to about 50 parts by volume of oxygen.

7. Method of claim 6 wherein said gas is a mixture of about 10 to about 40 parts by volume of CF_4 and about 90 to about 60 parts by volume of oxygen.

8. Method of claim 1 wherein the power is cycled between about 500 watts and about 50 watts.

9. Method of claim 1 wherein the flow of gas is about 10 to about 200 standard cubic centimeters per minute.

10. Method of claim 1 wherein the pressure during the etching is about 1.33 to 665 µbar (1 to 500 millitorr).

Patentansprüche

1. Verfahren zum Ätzen eines Artikels durch Plasma-Ätzen, bei dem der Artikel ein Substrat und darauf eine aus organischem Material bestehende Oberfläche umfaßt, das folgende Verfahrensschritte umfaßt:
Positionierung des zu ätzenden Artikels auf einer Kathode;
Einschließen der Kathode und des zu ätzenden Artikels in einen Behälter;
Einführen eines Ätzgases in den Behälter, wobei das Ätzgas eine Mischung aus einem Fluorkohlenstoff und Sauerstoff ist; und
Anlegen von Strom an die Kathode, wobei die Leistung periodisch zwischen einer niedrigeren und einer höheren Wattzahl schwankt, um dadurch die Ätzgeschwindigkeit des organischen Materials zu erhöhen.

2. Verfahren nach Anspruch 1, bei dem das organische Material aus der Gruppe ausgewählt wird, die aus Polyimiden, Polyamiden, Epoxidharzen, Phenolaldehydpolymeren und Polyolefinen besteht.

3. Verfahren nach Anspruch 2, bei dem die Oberfläche ein Polyimid umfaßt.

4. Verfahren nach Anspruch 1, bei dem das Gas einen Fluorkohlenstoff enthält, der aus der Gruppe ausgewählt wird, die aus CHF_3, CF_4 und C_2F_6 besteht.

5. Verfahren nach Anspruch 4, bei dem das Gas CF_4 enthält.

6. Verfahren nach Anspruch 5, bei dem das Gas eine Mischung aus etwa 1 bis etwa 50 Volumenteilen an CF_4 und etwa 99 bis etwa 50 Volumenteilen an Sauerstoff ist.

7. Verfahren nach Anspruch 6, bei dem das Gas eine Mischung aus etwa 10 bis etwa 40 Volumenteilen an CF_4 und etwa 90 bis etwa 60 Volumenteilen an Sauerstoff ist.

8. Verfahren nach Anspruch 1, bei dem die Leistung periodisch zwischen etwa 500 Watt und etwa 50 Watt schwankt.

9. Verfahren nach Anspruch 1, bei der der Gasfluß etwa 10 bis etwa 200 Standardkubikzentimeter pro Minute beträgt.

10. Verfahren nach Anspruch 1, bei dem der Druck während des Ätzens etwa 1,33 bis 665 µbar (1 bis 500 Millitorr) beträgt.

Revendications

1. Procédé pour graver un article par attaque par plasma, dans lequel cet article comprend un substrat portant une surface de matériau organique, qui comprend :

la mise en place de l'article à graver sur une cathode;

l'enfermement dans un récipient de la cathode et de l'artiche à graver;

l'introduction d'un gaz d'attaque dans ce récipient ce gaz d'attaque étant un mélange d'un fluorocarbure et d'oxygene; et

l'application d'énergie à la cathode, cette alimentation en énergie étant soumise à des cycles entre un wattage inférieur et un wattage supérieur de façon à augmenter la vitesse d'attaque du matériau organique.

2. Procédé suivant la revendication 1, dans lequel ce matériau organique est choisi dans le groupe consistant en polyimides, polyamides, résines époxy, polymères aldéhydephénoliques et polyoléfines.

3. Procédé suivant la revendication 2, dans lequel cette surface comprend un polyimide.

4. Procédé suivant la revendication 1 dans lequel ce gaz comprend un fluorcarbure choisi dans le groupe consistant en CHF_3,CF_4 et C_2F_6.

5. Procédé suivant la revendication 4, dans lequel ce gaz comprend du CF_4.

6. Procédé suivant la revendication 5, dans lequel ce gaz est un mélange d'environ 1 à environ 50 parties en volume de CF_4 et d'environ 99 à environ 50 parties en volume d'oxygène.

7. Procédé suivant la revendication 6, dans lequel ce gaz est un mélange d'environ 10 à environ 40 parties en volume de CF_4 et d'environ 90 à environ 60 parties en volume d'oxygène.

8. Procédé suivant la revendication 1, dans lequel l'alimentation en énergie est soumise à des cycles entre environ 500 W et environ 50 W.

9. Procédé suivant la revendication 1, dans lequel le débit de gaz est d'environ 10 à environ 200 cm^3/minute (conditions normales)

10. Procédé suivant la revendication 1 dans lequel la pression pendant l'attaque est d'environ 1,33 à 665 µbar (1 à 500 millitorr).

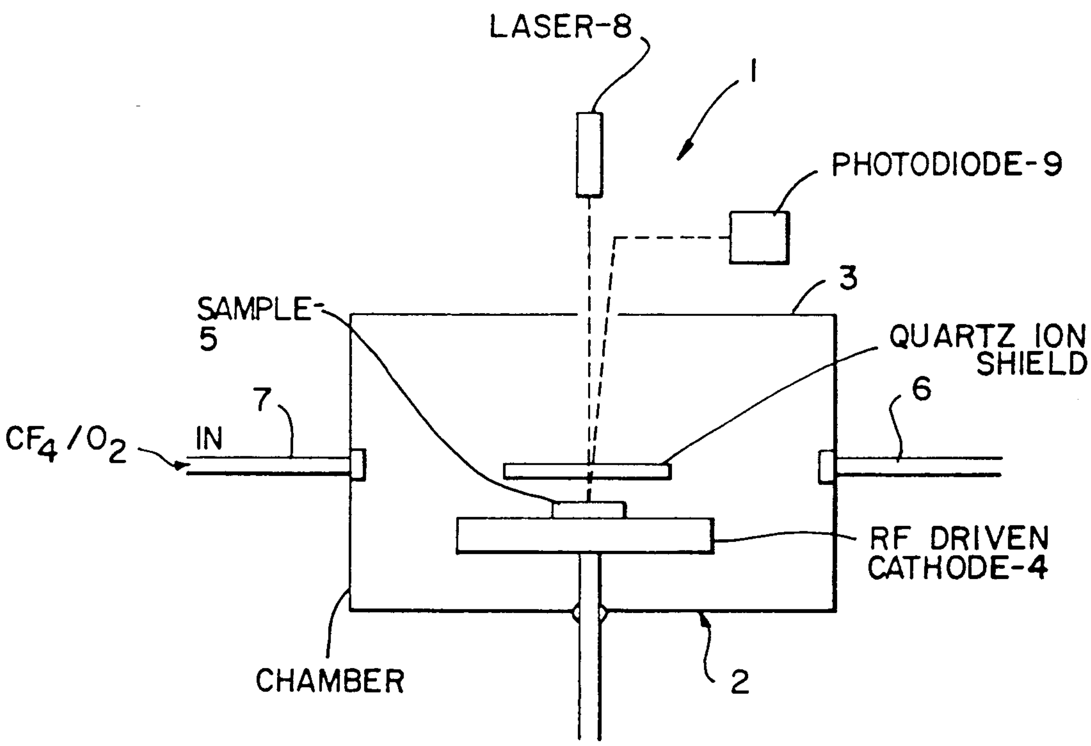
LASER-8
1
PHOTODIODE-9
3
SAMPLE-5
QUARTZ ION SHIELD
7
6
CF_4/O_2
IN
RF DRIVEN CATHODE-4
CHAMBER
2

FIGURE 1